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Characterization of the Dynamic Effects of Fiscal Shocks in a Small Open Economy

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The views expressed in this paper are those of the author.
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Contents

Acknowledgements iv
Abstract/Résumé v

1 Introduction 1

2 Specification of the Approach and Motivation 2

2.1 Data and estimation strategy 6

3 Quantitative Results 7

3.1 The effect of taxes 7

3.2 The effects of public expenditures 8

4 The Model 9

4.1 Households 9

4.2 Aggregators 12

4.3 Intermediate-goods sectors 14

4.4 Monetary authority 16

4.5 The government 16

5 Estimation Methodology 17

5.1 Estimation results 18

6 Results 20

7 Monetary Policy and the Transmission of Fiscal Shocks 21

8 Conclusion 22

References 23

Tables 26

Figures 29

Appendix: Construction of Average Tax Rates 33

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Abstract

The author studies the macroeconomic consequences of discretionary changes in the fiscal policy instruments for Canada. He adopts a semi-structural vector autoregression framework. Restrictions are based on institutional interactions between some policy and non-policy instruments that mimic a government's decision process. The author characterizes the actual economy's response to fiscal shocks, and proposes a theoretical model for a small open economy with nominal and real rigidities to test for the endogenous transmission mechanisms following shocks to government spending. He pursues a limited-information econometric strategy by comparing the theoretical impluse-response functions with the empirical ones, capturing the effects of a disturbance in government spending. Generally, the results of the model are very close to the observed reactions, especially for consumption, investment, exports, imports, and inflation; however, the model fails to predict the real exchange rate reaction.

JEL classification: E32, E62
Bank classification: Economic models; Exchange rates; Fiscal policy

Résumé

L'auteur se penche sur les conséquences macroéconomiques de modifications discrétionnaires apportées aux instruments de la politique budgétaire dans le contexte canadien. Son analyse repose sur un cadre semi-structurel d'autorégression vectorielle. Dans le but de simuler le processus décisionnel des autorités, l'auteur incorpore certaines restrictions, fondées sur le jeu des interactions institutionnelles d'une série d'instruments budgétaires et non budgétaires. Il décrit la réaction réelle de l'économie à des chocs budgétaires et propose un modèle théorique afin de tester les mécanismes de transmission endogènes des chocs que génère une variation imprévue des dépenses publiques dans une petite économie ouverte où existent des rigidités nominales et réelles. Pour représenter les effets de telles variations, il compare les profils de réaction théoriques aux profils empiriques dégagés, dans le cadre d'une méthode d'estimation à information limitée. En général, le modèle reproduit très bien les réactions observées, surtout celles de la consommation, de l'investissement, des exportations, des importations et de l'inflation, mais il ne réussit pas à prévoir celle du taux de change réel.

Classification JEL : E32, E62
Classification de la Banque : Modèles économiques; Taux de change; Politique budgétaire

1 Introduction

This paper characterizes the dynamic effects of fiscal policy on the Canadian economy, and investigates the ability of recent small open-economy New Keynesian models to reproduce these facts. To the author's knowledge, this type of exercise has not been carried out, since the literature emphasizes the monetary aspects of small open economies.

Given the ambiguity of interpreting shifts in fiscal stance, the literature has neglected the empirical characterization of these types of shocks for a long time.[1] However, some recent studies have contributed to the topic (e.g., Ramey and Shapiro 1997, Burnside, Eichenbaum, and Fisher 2004, Blanchard and Perotti 2002).

Some of these attempts use the "narrative approach" to identify several dates of military buildup. This approach was pioneered by Ramey and Shapiro (1997), and used later by Edelberg, Eichenbaum, and Fisher (1999) and Burnside, Eichenbaum, and Fisher (2004).[2] The advantage of this methodology is the exogenous aspect of the identified dates. Nevertheless, this way of extracting purely exogenous government shocks faces some limitations, mainly because the identified war dates are different in the sense that the military buildups are not financed identically, and therefore their consequences would be different. A second strategy for measuring fiscal policy stance is proposed by Blanchard and Perotti (2002). They use institutional information about the tax and transfers system to construct contemporaneous cross-elasticities between a set of the vector autoregression (VAR) variables. Conditional on these elasticities, they estimate an exactly identified VAR that contains a measure of real activity, government spending, and taxes.

In this paper, a VAR-based approach is proposed to identify fiscal shocks and their effects on key macroeconomic variables. More specifically, a semi-structural VAR approach is developed that leaves the relationship among macroeconomic and most non-policy variables unrestricted, but carries contemporaneous identification restrictions on a set of fiscal policy variables that arise from the government's policy decision. The main advantage of this approach is that it takes into consideration the overall measure of the government's policy stance, rather than focusing on exogenous innovations to policy. This method is applied to assess empirical facts related to the effect of fiscal policy innovations on macroeconomic variables in a small open economy using Canadian data. Of particular interest are the responses of consumption, investment, inflation, and current account variables to a variation in government spending. The main findings are as follows. First, as documented in earlier studies for U.S. data (e.g., Blanchard and Perotti 2002, Fatás and Mihov 2001a, and Mountford and Uhlig 2002) —conditional on shocks to government spending—consumption,

[1] Most fiscal reforms are preceded by parliamentary debates, which make them predictable; the economy can adjust even before these policies are implemented. This poses a challenge for identifying and assessing the effects of fiscal policy shocks. In addition, while the literature agrees that monetary policy seems to take place via unexpected changes in the interest rate, there is no consensus on the way fiscal policy appears. An increase in government spending could be accompanied by an increase in taxes, or a decrease in transfers, or both, which would also be unexpected.

[2] Ramey and Shapiro (1997) identify three dates of military buildups that coincide with the Korean War, the Vietnam War, and the Carter-Reagan administrations.

imports, and exports are positively correlated with public expenditures. Second, there is the negative effect of an unexpected rise in public purchases on investment. Third, the same shock leads to more than a one-year fall in CPI inflation. Fourth, higher taxes and increases in government spending, though interpreted as opposite demand shocks, give rise to real exchange rate appreciation.

In this paper, the New Keynesian theoretical framework is used to study the effects of shocks to government spending in a small open economy. In particular, nominal rigidities are incorporated into the prices of imported goods, the prices of local goods, and wages. These rigidities are introduced assuming monopolistically competitive firms that produce both imported and local goods, as well as households characterized by different labour skills. The model is extended by allowing the preferences to exhibit substitutability between private and public goods and habit formation in consumption. The model is estimated using a limited-information econometric strategy. In the same spirit as Christiano, Eichenbaum, and Evans (2001), government spending is characterized as an AR(1) process, and the dynamic effects of a fiscal disturbance on aggregate economic variables are compared with the corresponding ones obtained from a VAR. The same restrictions are used to identify the shocks to government spending in the empirical and the theoretical frameworks. In particular, the shocks to government spending have contemporaneous effects on aggregate variables, but not the opposite. On the one hand, unlike in Christiano, Eichenbaum, and Evans (2001), not only staggered wage contracts but also price stickiness contributes importantly to matching the empirical impulse-response functions. On the other hand, in aggregate, private and public consumptions are complements.

The remainder of this paper is organized as follows. Section 2 discusses the empirical approach used to identify the discretionary fiscal policy innovations. Section 3 reports the empirical results that are used to test the model introduced in section 4. Section 5 explains the estimation technique for some key structural parameters. Section 6 reports the main theoretical results. Section 7 discusses the role of the nominal interest rate rule on the transmission of fiscal shocks. Section 8 draws some conclusions.

2 Specification of the Approach and Motivation

The approach is based on the relaxation of the identification restrictions among the system's macroeconomic variables imposed in a standard structural VAR. In fact, in a semi-structural VAR, one only needs to impose some contemporaneous identification restrictions on a group of variables. This subsample of endogenous components is generally made up of the policy instruments. Bernanke and Mihov (1998) use this technique to identify monetary shocks. They assume that the monetary policy decision was based on three indicators bearing on the market for bank reserves: total reserves, the demand for borrowed reserves, and the federal funds rate.

For the identification of fiscal policy shocks, Blanchard and Perotti (2002) propose a structural VAR in which they adopt an innovative identification technique. They use a simple VAR with three variables: tax rate, government spending, and output. With respect

to the reaction of taxes to output shocks, they construct the appropriate elasticity by calculating the responsiveness of specific tax components to output changes.

In this paper, a similar method is applied for the fiscal policy instruments. To identify structural fiscal innovations, however, a semi-structural VAR is used with non-policy instruments, NP_t, policy instruments, P_t, and a sample of other macro-variables, Y_t, the reactions of which to fiscal shocks are examined.

Consider the following model:

$$NP_t = \sum_{i=0}^{k} B_i NP_{t-i} + \sum_{i=0}^{k} C_i P_{t-i} + \sum_{i=0}^{k} D_i Y_{t-i} + A^{NP} e_t^{NP}, \tag{1}$$

$$P_t = \sum_{i=0}^{k} E_i NP_{t-i} + \sum_{i=0}^{k} F_i P_{t-i} + \sum_{i=0}^{k} G_i Y_{t-i} + A^{P} e_t^{P}, \tag{2}$$

$$Y_t = \sum_{i=0}^{k} H_i NP_{t-i} + \sum_{i=0}^{k} I_i P_{t-i} + \sum_{i=0}^{k} J_i Y_{t-i} + A^{Y} e_t^{Y}. \tag{3}$$

The vector for fiscal policy instruments consists of: government spending, G, effective labour tax rates, τ^l, and effective capital tax rates, τ^k. The introduction of tax rates, instead of tax receipts, helps avoid the computing of elasticities between fiscal instruments and contemporaneous per-capita revenues, as in Blanchard and Perotti (2002). Vector NP contains monetary indexes necessary for the conduct of fiscal policy, which include the nominal 3-month treasury-bill rate, R, and inflation based on the consumption price index, π. Vector Y represents the set of macroeconomic variables, which include the real output, GDP, in addition to another changing variable, X: this paper attempts to describe the dynamic reaction of X to a structural shock to fiscal policy. Together, Y and NP mimic the properties of the actual economic situation and help explain changes in the fiscal instruments. Given this specification, e_t^{NP}, e_t^{P}, and e_t^{Y} are mutually non-correlated and can square with structural error terms.

This system is obviously not identifiable. To identify the dynamic effects of the structural fiscal policy shocks on the macro-variables of vector Y_t, it is assumed that reduced-form policy shocks are not immediately affected by the non-policy variables and, at the same time, by the macro-variables set. This does not seem to be a strong assumption, in that changes to government expenditures and taxes are not necessarily undertaken for reasons related to contemporaneous reaction to macroeconomic conditions. One argument in favour of this assumption is that quarterly data are used, which does not allow enough time for fiscal adjustments, given the contemporaneous state of the economy embedded in the macro-variables. Nonetheless, it can be argued that government spending still affects, without delay, the current output and therefore other macro-variables.

Putting aside the non-policy situation, it is this author's conviction that, for institutional concerns, the fiscal authority adjusts its discretionary decisions given a set of fiscal policy instruments that enter explicitly into its budget rule. Consequently, the assumption in this

paper is that the government policy follows an expenditures regime or a taxation regime. In reality, the fiscal authority has two main macroeconomic concerns: the sustainability of public accounts and the regulation of aggregate demand. These objectives cannot be followed without adjusting, simultaneously and in a consistent manner, several instruments of the government.

Furthermore, it is assumed in this paper that non-policy variables are affected by the policy instruments with a one-period delay, except for interest rates. This variable should be treated in the VAR with great care. In fact, in this paper, monetary instruments are allowed to react immediately to structural fiscal shocks. Leeper (1993), Leeper and Sims (1994), and Sims (1994), among others, consider that fiscal and monetary policies are intimately related. To illustrate this assumption, suppose that the monetary authority raises the nominal interest rate strongly in response to an increase in nominal variables like inflation or money growth; the fiscal authority should consequently increase taxes, given the contemporaneous increase in real debt. In a theoretical model, the refusal of the fiscal authority to increase taxes would violate the intertemporal government budget rule, resulting in an undefined equilibrium. On the other hand, the monetary authority should also adjust if the fiscal authority refuses to change taxes, by avoiding a great increase in the nominal interest rate. Given the fact that the fiscal authority does not have the opportunity to freely adjust its instruments each quarter to changes in NP, in this paper the monetary authority is permitted to adjust only to changes in variables under government control.

All macro-variables react with a 1-quarter delay to all movements in other variables that are included in Y and NP.[3]
After some transformations to (1), (2), and (3), the empirical system can be derived:

$$R(L)\begin{bmatrix} NP_t \\ P_t \\ Y_t \end{bmatrix} = \begin{bmatrix} u_t^{NP} \\ u_t^{P} \\ u_t^{Y} \end{bmatrix}. \tag{4}$$

where $R(L)$ is a matrix of polynomials in the lag operator L and $R(0) = I$, and u_t^{NP}, u_t^{P}, and u_t^{Y} are reduced-form shocks on the specific variables' components. Particularly, u_t^{NP} is composed by reduced-form shocks on inflation, u_t^{π}, and on the nominal interest rate, u_t^{r}; u_t^{P} contains shocks on labour taxes, u_t^{l}, capital taxes, u_t^{k}, and government spending, u_t^{g}; u_t^{Y} contains output residuals, u_t^{GDP}, and an additional variable residual, u_t^{X}.

The following relationship is attained between the reduced-form innovations and the structural ones:

$$\begin{bmatrix} \Omega_{1,1} & \Omega_{1,2} & 0 \\ 0 & \Omega_{2,2} & 0 \\ 0 & \Omega_{3,2} & \Omega_{3,3} \end{bmatrix}\begin{bmatrix} u_t^{NP} \\ u_t^{P} \\ u_t^{Y} \end{bmatrix} = \begin{bmatrix} \Upsilon_{1,1} & 0 & 0 \\ 0 & \Upsilon_{2,2} & 0 \\ 0 & 0 & \Upsilon_{3,3} \end{bmatrix}\begin{bmatrix} e_t^{NP} \\ e_t^{P} \\ e_t^{Y} \end{bmatrix}. \tag{5}$$

[3] Bernanke and Mihov (1998) make similar assumptions. However, the main idea is that macro-variables do not respond contemporaneously to monetary shocks. For that reason, the variables introduced in their VAR are based on monthly data.

Hence, the core of the identification strategy are matrices $\Omega_{2,2}$ and $\Upsilon_{2,2}$, which shape the relationships among the fiscal innovations and the fiscal shocks:

$$\Omega_{2,2} u_t^F = \Upsilon_{2,2} e_t^F. \tag{6}$$

Once contemporaneous interactions between fiscal instruments are identified, attention is turned to the simultaneous reactions of the interest rate and macroeconomic variables to each element in e_t^F.

Once the initial VAR is estimated, the following identification system is proposed:

$$u_t^r = \gamma_1^r u_t^l + \gamma_2^r u_t^k + \gamma_3^r u_t^g + \gamma_4^r u_t^y + e_t^r, \tag{7}$$

$$u_t^l = \gamma_1^l e_t^k + \gamma_2^l e_t^g + e_t^l, \tag{8}$$

$$u_t^k = \gamma_1^k e_t^l + \gamma_2^k e_t^g + e_t^k, \tag{9}$$

$$u_t^g = \gamma_1^g e_t^l + \gamma_2^g e_t^k + e_t^g. \tag{10}$$

Equation (7) states that unexpected movements in interest rates within a quarter, u_t^r, can be due to one of five factors: the response to reduced-form shocks to the labour tax rate, captured by $\gamma_1^r u_t^l$, the response to reduced-form shocks to the capital tax rate, captured by $\gamma_2^r u_t^k$, the response to reduced-form shocks to government spending, captured by $\gamma_3^r u_t^g$, the response to reduced-form shocks to a macro-variables set, captured by $\gamma_4^r u_t^y$, and the response to structural shocks to monetary policy, captured by e_t^r. A similar interpretation applies to unexpected movements in labour taxes, capital taxes, and government spending, with the difference that structural shocks appear, rather than reduced-form ones, when all these innovations are on fiscal instruments, obviously known by all government services.

Given the estimated shocks vector, u_t, and some reasonable, but not testable, restrictions on the way the government synchronizes decisions about instrument variations, the system's parameters, as well as the variances of structural shocks, can be estimated.

Assume that the policy-maker uses a government spending regime. Consequently, the main concern of the fiscal authority during the decision process is the choice of expenditures in services and goods. Thus, taxes will adjust. Formally, this leads to $\gamma_1^g = \gamma_2^g = 0$.

Blanchard and Perotti (2002) and Fatás and Mihov (2001a,b) estimate the VAR with the total tax collection. Because, in this paper, effective tax rates are included as endogenous variables, there is a need to deal explicitly with the way taxes react to changes in government variables or macro-data. Blanchard and Perotti (2002) mix a VAR procedure with generated automatic responses of taxes and spending to economic activity from institutional information on tax collection and transfers, to find co-movements of taxes and activity. Under the choice of tax measures, this procedure can be avoided and, even if one were to believe in Blanchard and Perotti's assumptions, this paper argues that it is very

informative to define taxes as effective labour and capital tax cuts as a percentage levied on revenues.

The foregoing assumptions lead to an overidentified system that draws non-linearity in the parameters that summarize the contemporaneous reactions of variables to structural shocks. As a result, a generalized method of moments (GMM) procedure is adopted within the second step of estimation. After isolating the reduced-form shocks, their second moments are employed to identify the components of Ω and Υ. The specification of the model is then tested using the value of Hansen's J-test.

2.1 Data and estimation strategy

The estimation is based on Canadian data that cover the sample period 1962Q1–2002Q4, the longest period for which all data are available on the variables of the VAR. The number of lags is set to 4, to ensure non-autocorrelation for the residuals of the simultaneous equations.

It should be made clear that there exists a trade-off in the way Y_t, the set of macrovariables, is specified. On the one hand, to assess the responses of many key variables to a fiscal shock, one should deal with a large number of endogenous variables during the VAR estimation. This is specially true if the aim is to specify the process by which the fiscal authority arrives at a policy decision. This requires estimating a large number of parameters. On the other hand, if few variables are included in the VAR, an accurate specification may be missed, which would result in a significant omitted-variable bias. The solution adopted in this paper is to leave the specification of the non-policy and the policy variables unchanged and include the variable of interest separately from the other macroeconomic variables, in addition to real GDP. The NP_t vector contains the CPI inflation rate and nominal interest rate for the 3-month treasury bill. For fiscal policy instruments, P_t, average tax rates on labour and capital revenues are considered, as well as the log level of time t real government spending.[4] Tax rates are calculated following the method of Jones (2002), which is also similar in spirit to the method of Mendoza, Razin, and Tesar (1994). A detailed explanation of the method is provided in the appendix.[5] Despite the high level of information carried within the generated taxes, this method still has some problems. In fact, it does not offer information on statutory tax rates and the income distribution per tax bracket. Mendoza, Razin, and Tesar (1994) compare their generated series of effective average tax rates with those that capture the marginal tax rates on average income, as proposed by Barro and

[4] Output and government spending are defined in logarithms of their per-capita level. Non-stationarity is not of interest in this framework, given that the estimates of $R(L)$ components, found in the first step, embody implicitly the long-term relationships between non-stationary variables. As a consequence, it is not possible to find interesting results using subsamples, because that would presume the use of a large number of observations.

[5] The advantages of this method, as explained by Mendoza, Razin, and Tesar, are summarized in three points. First, it is quite precise, in that it considers the net effect of some subaccounts in the calculation of net paid taxes, such as credits, exemptions, and deductions. Second, it allows a distinction to be made between taxes on labour income and taxes on capital income. Third, it incorporates the effects of taxes not filed with individual income tax returns, such as social security contributions and property taxes, on factor income taxation.

105-00801/

Sahasakul (1986), and find that, despite the different level of taxes, they display very similar trends.

3 Quantitative Results

To illustrate the macroeconomic effects of fiscal policy shocks, the economy is subjected to a one-standard-deviation unexpected increase in one of the three policy instruments. In Figure 1, the solid lines represent the estimated coefficients of the dynamic response functions; confidence intervals of 90 per cent are computed from the Integrated Monte Carlo method using 500 simulations.

For estimation, a two-step efficient GMM procedure is used. The first step consists of equation-by-equation ordinary least squares (OLS) estimation of the coefficients of the VAR system. The second step involves matching the second moments implied by the particular theoretical model being estimated with the covariance matrix of the reduced-form shocks. Two types of tests are performed: (i) a test of overidentification restrictions based on the minimized value of the sample criterion function (Hansen's J-test), and (ii) hypothesis tests on the estimates of the structural parameters. Table 1 shows the parameter estimates and their standard deviations. The parameters γ_{12}^{l} and γ_{12}^{k}, which capture the reaction of taxes to an increase in expenditures, are positive: 0.08 and 0.06, respectively. This suggests that there is an immediate increase in both taxes in response to an increase in the expenditure components. The values of γ_{11}^{r}, γ_{12}^{r}, and γ_{13}^{r} summarize the spontaneous reactions of nominal interest rates to reduced-form shocks on taxes and government expenditures. At this stage, however, it is difficult to understand monetary policy's degree of responsiveness to fiscal shocks, given the non-linearity between the parameters resulting from the simultaneous reactions of different variables in the VAR. The net effect of one shock will depend on these parameters, and will be computed from the initial variations in the impulse-response functions.

3.1 The effect of taxes

The results for effective labour and capital taxes are presented in Figure 1, columns 1 and 2, respectively. A strong fall in output, having a median minimum of -1 per cent, occurs 6 quarters after an increase in labour taxes. Similarly, an unexpected increase in capital taxes has a negative and persistent effect on output: it falls by 0.2 per cent in the median, but it is not statistically significant.

The results suggest that, for the Canadian economy, both taxes move simultaneously, with a high degree of contemporaneous correlation, which is significantly positive and equals 0.37, on average. In addition, interest rate impulse responses show a statistically significant and substantial decrease, where the minimum is reached after about 10 quarters: the median falls by -0.99 and -0.41 per cent after a shock on labour and capital taxes, respectively. The results also show that monetary policy sustains the decisions made by the fiscal authority on impact when interest rates rise by 27 and 10 basis points. This is not the case in the

medium and long term.

Table 2, in its columns that pertain to effective labour and capital taxes, shows responses for different types of consumption to tax increases. The behaviour of total private consumption largely mimics that of output: it decreases in impact and continues until the fourth quarter. This is valid for both tax measures and for the different consumption components, with various levels of significance. Similarly to consumption, total investment and its components fall gradually once labour or capital tax is positively shocked, except that the decrease in investment is larger following a higher labour tax. The same is true for real wages. Wages are deflated using the CPI and GDP deflator. Results reveal that, for both measures of real wages, the negative effect of labour tax is greater than the capital tax effect.

Table 2 also shows evidence of variables intimately related to current account determination. Clearly, both taxes have a positive effect on imports, following hump-shaped trajectories, where a peak is reached roughly after three years. Following a labour tax shock, real exports fall significantly (by 1.5 per cent), but increase greatly a few years later. The conclusion drawn from studying the data on the exchange rate is that a positive shock on taxes significantly appreciates the Canadian dollar, especially in response to a labour tax contractionary shock. The latter occurs slowly, reaching a 1.8 per cent increase in local currency after more than two years.

3.2 The effects of public expenditures

Figure 1 and the last six columns of Table 2 describe the effects of an unexpected 1 per cent increase in government expenditures. Several results of these plots are worth noting. Figure 1 shows an immediate increase in output of about 0.1 per cent, although this effect is barely significant and not persistent. Counterintuitively, inflation decreases, although not significantly, for 4 quarters. A fall in inflation is hard to reconcile with the predictions of theoretical general-equilibrium models. In the case of interest rate responses, the monetary authority accommodates government decisions regarding spending adjustments. The bottom row of Figure 1 shows an immediate significant fall in interest rates by almost 10 basis points, which persists for roughly a year.

Many recent studies find a positive correlation between consumption and government spending, conditional on shocks to the latter (e.g., Blanchard and Perotti 2002, Perotti 2002, Fatás and Mihov 2001b, Mountford and Uhlig 2002, Galí, Lopez-Salido, and Vallés 2002, and Bonakez and Rebei 2003). Most of these studies find this important result for the U.S. economy. With the set of identification restrictions used in this study, the same result is found for Canadian data. Specifically, the consumption rows in Table 2 show that a policy-induced rise in government spending is associated with a delayed significant and persistent increase in total consumption and its components, especially in non-durable goods: a raise of 0.18 per cent for total consumption, and 0.22 per cent for non-durable goods. Indeed, this presents a big challenge for theoretical models with a tractable Ricardian environment.

Total investment responds negatively to the government spending shock. Table 2 shows a fall of about 0.7 per cent attained after 6 quarters, and of 0.8 per cent for non-residential

investment.

Surprisingly, the dynamic-response functions of current account key variables reveal important and significant effects of an unexpected government spending rise. First, real exports respond by a 0.58 per cent increase after 7 quarters. Second, imports react strongly and positively, reaching an increase of 1.4 per cent after one year. Third, the real exchange rate appreciates significantly by 1.2 per cent after three years. The latter result is quite hard to understand, given the appreciation of the real exchange rate in response to an increase in taxes, discussed above. Because fiscal instruments, generally, affect real variables through changes in aggregate demand, it is puzzling to find that an expansionary government spending shock, and a contractionary tax shock, could have a similar impact on real exchange rates in both dynamic and quantitative aspects.

4 The Model

The economy modelled is small, in that it faces fixed prices on world markets for imported intermediate goods. The economy's domestic output is an imperfect substitute for foreign goods, and it faces a downward-sloping demand curve for its output on world markets. It faces an upward-sloping supply curve for funds on international capital markets.

4.1 Households

The households are endowed with differentiated labour skills. I kinds of workers are distinguished by the type of labour force they are able to supply. This assumption implies that households compete monopolistically in the labour market, which allows them to have market power on wage-setting.

Households' preferences are described by the expected utility function,

$$U_0(i) = E_0 \sum_{t=0}^{\infty} \beta^t u\left(\tilde{c}_t(i), \frac{M_t(i)}{P_t}, h_t(i)\right), \tag{11}$$

where $\beta \in (0,1)$ is the discount factor; c_t is the household consumption index; $\frac{M_t}{P_t}$ is the end-of-period real money holdings, where M_t is the nominal balances; and P_t is a consumption price index for period t. The single-period utility function is specified as

$$u(\cdot) = \frac{1}{1-\omega_1}\left(\frac{\tilde{c}_t(i)}{\tilde{c}_{t-1}(i)}\right)^{1-\omega_1} + \frac{\eta_1}{1-\omega_2}\left(\frac{M_t(i)}{P_t}\right)^{1-\omega_2} + \frac{\eta_2}{1-\omega_3}\left(1-h_t(i)\right)^{1-\omega_3}, \tag{12}$$

where $\frac{1}{\omega_1}$, $\frac{1}{\omega_2}$, and $\frac{1}{\omega_3}$ represent, respectively, the intertemporal elasticities of substitution for the consumption index, real balances, and leisure. The parameter $\gamma \in (0,1)$ captures the degree of habit formation in the composite consumption.

Following Christiano and Eichenbaum (1992), consumption is assumed to be composed of private and public consumption. However, both types of consumption are allowed to

be intratemporal substitutes or complements, depending on the parameterization of the constant elasticity of substitution (CES) composite good, $\tilde{c}$, defined as follows:

$$\tilde{c}_t = \left[a c_t^{\frac{\zeta-1}{\zeta}} + (1-a) g_t^{\frac{\zeta-1}{\zeta}} \right]^{\frac{\zeta}{\zeta-1}}. \tag{13}$$

where $\zeta (> 0)$ is the elasticity of substitution between private and public consumption. The lower is ζ, the higher is the complementarity between the two types of consumption. $(1-a)$ can be interpreted as the share of public goods in the total consumption.[6] Typically, this form of utility implies that agents do not necessarily feel worse off when g_t is increased.

Capital adjustment costs are required in dynamic open-economy models that differentiate physical from financial assets, and in order to prevent the instantaneous adjustment of the domestic marginal product of capital to the world interest rate. This cost is specified as:

$$CAC_t = \frac{\varphi_k}{2} \left(\frac{i_t}{k_t} - \delta \right)^2 k_t. \tag{14}$$

where $\varphi_k (\geqslant 0)$ is the capital adjustment cost parameter, $i_t \equiv k_{t+1} - (1-\delta) k_t$ is the investment, and $\delta \in (0,1)$ is the constant capital depreciation rate.

The household's budget constraint is given by

$$\begin{aligned} & P_t \left[c_t(i) + i_t(i) + CAC_t(i) \right] + M_t(i) + \frac{bd_t(i)}{R_t} + \frac{e_t bd_t^*(i)}{\kappa_t R_t^*} \\ \leq \; & (1-\tau_t^k) R_{kt} k_t(i) + \tau_t^k \delta P_t k_t(i) + (1-\tau_t^h) W_t(i) h_t(i) + \\ & M_{t-1}(i) + bd_{t-1}(i) + e_t bd_{t-1}^*(i) + T_t + D_t. \end{aligned} \tag{15}$$

Factor income is taxed at an average marginal tax rate, τ_t, with a provision for a depreciation allowance.

The variables bd_t^* and bd_t are foreign and domestic bonds purchased in time t. R_t and R_t^* denote the gross nominal domestic and foreign interest rates between t and $t+1$, respectively. e_t is the nominal exchange rate (the price of foreigners' currency in domestic currency units). The variable κ_t is a measure of a risk premium that reflects temporary departures from uncovered interest parity. The household also receives $D_t = D_t^d + D_t^m$, nominal profits, from monopolistic intermediate firms that produce domestic output and import goods, and T_t as a lump-sum nominal transfer from the fiscal authority.

$P_{d,t}$ is the producer price index for locally produced goods. This price is used as a numeraire. Thus, the variables are defined as $m_t = \frac{M_t}{P_{d,t}}$, $p_t = \frac{P_t}{P_{d,t}}$, $w_t = \frac{W_t}{P_{d,t}}$, $r_{k,t} = \frac{R_{k,t}}{P_{d,t}}$, and the locally produced goods inflation $\pi_{d,t} = \frac{P_{d,t}}{P_{d,t-1}}$.

The risk premium, κ_t, is a convex positive function with respect to the fraction of the net foreign assets level over output, which captures the value of output-weighted foreign

[6] Cooper and Johri (1997) describe in detail the complementarity or the substitutability between private and public consumption. Their estimated model suggests evidence of dynamic complementarity.

debt in the private sector:

$$\log(\kappa_t) = \varphi \left[\exp\left(\frac{e_t b d_t^*}{P_{d,t} y_t} \right) - 1 \right]. \tag{16}$$

given that $bd_t^* = \int_0^1 bd_t^*(i)di$.

The foreign nominal interest rate, R_t^*, evolves according to an exogenous autoregressive process. Given that this economy is small, it has no effect on the world's nominal interest rates.

Households also face a no-Ponzi-game restriction:

$$\lim_{T \to \infty} \left(\prod_{t=0}^{T} \frac{1}{\kappa_t R_t^*} \right) bd_T^* = 0. \tag{17}$$

Each household chooses $\left\{ c_t(i), M_t(i), \tilde{W}_t(i), k_{t+1}(i), bd_t^g(i), bd_t(i) \right\}$ to maximize the expectation of the discounted sum of its utility flows subject to the budget constraint, equation (15), to the demand by intermediate firms for their labour type i, $h_t = \left(\frac{w_t}{w_t(i)} \right)^{-\sigma} h_t(i)$, and to equation (17). The first-order conditions are:

$$p_t \lambda_t(i) = a \tilde{c}_t(i)^{\frac{1}{\xi} - \omega_1} c_t(i)^{-\frac{1}{\xi}} \left[\tilde{c}_{t-1}(i)^{\gamma(\omega_1 - 1)} - \beta \gamma \tilde{c}_{t+1}(i)^{(1-\omega_1)} \tilde{c}_t(i)^{(1+\gamma)(\omega_1 - 1)} \right]. \tag{18}$$

$$\eta_1 m_t^{-\omega_2}(i) + p_t \lambda_t(i) \left[\frac{1}{R_t} - 1 \right] = 0. \tag{19}$$

$$\begin{aligned} \beta E_t \Bigg\{ p_{t+1} \lambda_{t+1}(i) \Bigg[(1 - \tau_{t+1}^k) \frac{r_{k,t+1}}{p_{t+1}} + [1 - \delta(1 - \tau_{t+1})] + \varphi_k \left(\frac{k_{t+2}(i)}{k_{t+1}(i)} - 1 \right) \frac{k_{t+2}(i)}{k_{t+1}(i)} \\ - \frac{\varphi_k}{2} \left(\frac{k_{t+2}(i)}{k_{t+1}(i)} - 1 \right)^2 \Bigg] \Bigg\} = p_t \lambda_t(i) \left[1 + \varphi_k \left(\frac{k_{t+1}(i)}{k_t(i)} - 1 \right) \right]. \end{aligned} \tag{20}$$

$$\frac{\lambda_t(i)}{R_t} = \beta E_t \left[\frac{1}{\pi_{d,t+1}} \lambda_{t+1}(i) \right]. \tag{21}$$

$$\frac{\lambda_t(i)}{\kappa_t R_t^*} = \beta E_t \left[\frac{1}{\pi_{d,t+1}} \frac{e_{t+1}}{e_t} \lambda_{t+1}(i) \right]. \tag{22}$$

where λ_t is the Lagrangian multiplier of the budget constraint.

One other first-order condition corresponds to the rule of setting nominal wages when household i is allowed to adjust W. This happens with a probability $(1 - d_w)$ at the beginning of each period. Then, maximizing utility with respect to nominal wage i yields:

$$\sum_{l=0}^{\infty} \beta^l d_w^l E_t \left[\eta_2 \frac{\sigma}{\sigma - 1} (1 - h_{t+l}(i))^{-\omega_3} + (1 - \tau_{t+l}^h) \frac{\tilde{W}_t(i)}{P_{t+l}} \Lambda_{t+l}(i) \right] h_{t+l}(i) = 0. \tag{23}$$

The wage index in each period $t = 0, ..., \infty$ evolves over time according to the recursive form given by:

$$W_t = \left[d_w W_{t-1}^{1-\sigma} + (1 - d_w) \tilde{W}_t^{1-\sigma} \right]^{\frac{1}{1-\sigma}}. \tag{24}$$

4.2 Aggregators

It is assumed that there are three levels of aggregation in the economy, and therefore three representative competitive firms: (i) a firm that combines a continuum of differentiated domestic intermediate goods to produce a composite domestic output, y_t; (ii) a firm that combines a continuum of differentiated imported intermediate goods to produce a composite imported output, y_t^m; and (iii) a firm that uses both outputs to produce a final good divided between consumption, investment, government spending, and intermediate goods necessary for the local production process.

4.2.1 Composite domestic output

The composite domestic output, Y_t, is produced using a CES technology that uses a continuum of domestic intermediate goods, y_{jt}, as inputs

$$y_t \leq \left(\int_0^1 y_t(j)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}}, \qquad \theta > 1. \tag{25}$$

The profit maximization problem is

$$\max_{\{y_t(j)\}} P_{d,t} y_t - \int_0^1 P_{d,t}(j) y_t(j) dj, \tag{26}$$

subject to (25), and where $P_{d,t}(j)$ is the price of the domestic intermediate output $y_t(j)$.

The first-order conditions imply that the demand for the domestic intermediate output, $y_t(j)$, is

$$y_t(j) = \left(\frac{P_{d,t}(j)}{P_{d,t}} \right)^{-\theta} y_t, \tag{27}$$

and the domestic finished-output price, $P_{d,t}$, is given by

$$P_{d,t} = \left(\int_0^1 P_{d,t}(j)^{1-\theta} dj \right)^{\frac{1}{1-\theta}}. \tag{28}$$

The composite domestic output, y_t, is divided between domestic use, y_t^d, and exports, y_t^x, so that $y_t = y_t^d + y_t^x$.

It is assumed that the foreigners' demand function for domestic exports is given by[7]:

[7] This condition can be derived from a foreign importing firm which combines non-perfectly substitutable imported goods. Kollman (2002) and Bergin (2003) use a similar specification.

$$y_t^x = \alpha_x \left(\frac{P_{d,t}}{e_t P_t^*} \right)^{-\kappa} y_t^*. \tag{29}$$

where P_t^* is the foreign-currency price index in the foreign economy and y_t^* is the foreigners' outputs. The parameter $\kappa > 0$ is foreigners' demand elasticity for domestic exports, and $\alpha_x > 0$ is a parameter that determines the fraction of the domestic exports in the foreigners' spending. The domestic exports form an insignificant fraction for the foreigners' spending, and receive negligible weight in the foreign-currency price index. Thus, the domestic economy is small.

The foreign variables P_t^* and y_t^* are both exogenous and follow autoregressive processes.

4.2.2 Composite imported output

The composite imported output, y_t^m, is produced using a CES technology that uses a continuum of imported intermediate goods $y_t^m(j)$ as inputs:

$$y_t^m \leq \left(\int_0^1 (y_t^m(j))^{\frac{\vartheta-1}{\vartheta}} dj \right)^{\frac{\vartheta}{\vartheta-1}}, \qquad \vartheta > 1. \tag{30}$$

The CES between intermediate imported goods is given by ϑ.

The profit-maximization problem implies the following demand function for intermediate imported goods, $y_t^m(j)$:

$$y_t^m(j) = \left(\frac{P_{m,t}(j)}{P_{m,t}} \right)^{-\vartheta} y_t^m, \tag{31}$$

and the index price for the composite imported goods is

$$P_{m,t} = \left(\int_0^1 P_{m,t}(j)^{1-\vartheta} dj \right)^{\frac{1}{1-\vartheta}}. \tag{32}$$

4.2.3 Final-goods production

The final good, Z_t, is produced by a competitive firm that uses y_t^d and y_t^m as inputs in the following CES technology:

$$z_t = \left[\alpha_d^{\frac{1}{\nu}} (y_t^d)^{\frac{\nu-1}{\nu}} + \alpha_m^{\frac{1}{\nu}} (y_t^m)^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}}. \tag{33}$$

where α_d and α_m are positive and sum to unity. ν is positive and measures the elasticity of substitution between foreign and local goods in the consumer's basket. The final good, z_t, is used for domestic consumption, c_t; investment, i_t; inputs of intermediate goods engaged in the production process, x_t; government purchases, g_t; and capital adjustment costs, CAC_t.

The profit function is

$$\max_{\{y_t^d, y_t^m\}} P_t z_t - P_{d,t} y_t^d - P_{m,t} y_t^m. \tag{34}$$

subject to (33), and where $P_{d,t}$ is the price of the composite domestic output, y_t, with $P_{m,t}$ being the price of the imported good, y_t^m, in the domestic currency.

The profit maximization implies that

$$y_t^d = \alpha_d \left(\frac{P_{d,t}}{P_t} \right)^{-\nu} z_t, \tag{35}$$

$$y_t^m = \alpha_m \left(\frac{P_{m,t}}{P_t} \right)^{-\nu} z_t, \tag{36}$$

which are the domestic and imported intermediate-good demand functions. Furthermore, the final-good price, P_t, which is used as the price index, is given by

$$P_t = \left[\alpha_d (P_{d,t})^{1-\nu} + \alpha_m (P_{m,t})^{1-\nu} \right]^{1/(1-\nu)}. \tag{37}$$

4.3 Intermediate-goods sectors

4.3.1 Production of domestic intermediate goods

The intermediate firm, j, uses a combination of other intermediate goods, $x_t(j)$, $k_t(j)$, and $h_t(j)$, to produce $y_t(j)$ domestic intermediate output, which it sells at the price $P_{d,t}(j)$. The firm uses the technology

$$y_t(j) \leq x_t(j)^{\phi} \left[k_t(j)^{\alpha} (A_t h_t(j))^{1-\alpha} \right]^{1-\phi}, \quad \alpha \quad \text{and} \quad \phi \in (0,1), \tag{38}$$

where A_t is an exogenous technology following a stochastic process.

The intermediate good, $x_t(j)$, is a composite of all types of non-exported and imported goods. For simplicity, it is assumed that $x_t = \int_0^1 x_t(j)dj$ is a fraction of the composite finite good, z_t.

The labour input is a composite of all types of labour skills by which households are identified. Specifically:

$$h_t(j) = \left(\int_0^1 h_t(j,i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}}, \tag{39}$$

where σ is the elasticity of substitution between different labour skills. Given the problem of a labour aggregator, the following aggregate labour price can be derived:

$$W_t = \left(\int_0^1 W_t(i)^{1-\sigma} di \right)^{\frac{1}{1-\sigma}}. \tag{40}$$

The intermediate-good-producing firm chooses $x_t(j)$, $k_t(j)$, $h_t(j,i)$ (for $i = 0...1$), and $P_{d,t}(j)$, which maximize its expected weighted real profits, given that the firm can adjust its price only once every $\frac{1}{1-d_p}$ periods, on average.

The intermediate firm's problem is as follows:

$$\max_{\{x_t(j), k_t(j), h_t(j,i), P_{d,t}(j)\}} E_t \left[\sum_{l=0}^{\infty} (\beta d_p)^l \left(\frac{\lambda_{t+l}}{\lambda_t} \right) D_{t+l}^d(j) / P_{d,t+l} \right], \tag{41}$$

where

$$D_t^g(j) = P_{d,t}(j)y_t(j) - R_{kt}k_t(j) - \left(\int_0^1 W_t(i)h_t(j,i)di\right) - P_t x_t(j). \tag{42}$$

subject to

$$\left(\frac{\tilde{P}_{d,t}(j)}{P_{d,t}}\right)^{-\theta} Y_t \leq x_t(j)^o \left[k_t(j)^\alpha (A_t h_t(j))^{1-\alpha}\right]^{1-o}. \tag{43}$$

Here, $\xi_t > 0$ is the real marginal cost, $\tilde{P}_t(j)$ is the level of the price commitment, and $\lambda_t > 0$ is the marginal utility of consumption.

The first-order conditions are

$$r_{kt} = \alpha(1-o)\xi_t(j)\frac{y_t(j)}{k_t(j)}, \tag{44}$$

$$w_t(j) = (1-\alpha)(1-o)\xi_t(j)\frac{y_t(j)}{h_t(j)}\left[\frac{h_t(j,i)}{h_t(j)}\right]^{\frac{-1}{\sigma}}, \tag{45}$$

$$p_t(j) = o\xi_t(j)\frac{y_t(j)}{x_t(j)}, \tag{46}$$

$$\tilde{P}_{d,t}(j) = \left(\frac{\theta}{\theta-1}\right)\frac{E_t\sum_{l=0}^{\infty}\beta^l d_p^l \frac{\lambda_{t+l}}{\lambda_t}\xi_{t+l}(j)y_{t+l}\left(P_{d,t+l}\right)^\theta}{E_t\sum_{l=0}^{\infty}\beta^l d_p^l \frac{\lambda_{t+l}}{\lambda_t}y_{t+l}\left(P_{d,t+l}\right)^{\theta-1}}. \tag{47}$$

Prices in each period $t = 0, ..., \infty$ evolve over time according to the recursive form given by:

$$P_{d,t} = \left[d_p P_{d,t-1}^{1-\theta} + (1-d_p)\tilde{P}_{d,t}^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{48}$$

4.3.2 Importers of foreign intermediate goods

It is assumed that the country imports a continuum of foreign intermediate goods indexed also by $j \in (0,1)$. There is monopolistic competition in the imported intermediate-goods market. Each imported intermediate good is used by a perfectly competitive firm to produce a composite imported output, y_t^m.

Importer j chooses the price, $P_{m,t}(j)$, that maximizes its weighted expected profits.

The importer maximizes

$$\max_{\{P_{m,t}(j)\}} E_t\left[\sum_{l=0}^{\infty}(\beta d_p)^l\left(\frac{\lambda_{t+l}}{\lambda_t}\right)D_{t+l}^m(j)/P_{d,t+l}\right], \tag{49}$$

where

$$D_t^m(j) = \left(\tilde{P}_{m,t}(j) - e_t P_t^*\right)\left(\frac{P_{m,t}(j)}{P_{m,t}}\right)^{-\theta} y_t^m. \tag{50}$$

The first-order condition of this optimization problem is:

$$P_{m,t}(j) = \left(\frac{\theta}{\theta-1}\right) \frac{E_t \sum_{l=0}^{\infty} \beta^l d_p^l \frac{\lambda_{t+l}}{\lambda_t} y_{t+l}^m (P_{m,t+l})^{\theta} \frac{1}{P_{G,t+l}} c_{t+l} P_{t+l}^c}{E_t \sum_{l=0}^{\infty} \beta^l d_p^l \frac{\lambda_{t+l}}{\lambda_t} y_{t+l}^m(j) (P_{m,t+l})^{\theta} \frac{1}{P_{G,t+l}}}. \tag{51}$$

given that:

$$P_{m,t} = \left[d_p P_{m,t-1}^{1-\theta} + (1-d_p) P_{m,t}^{1-\theta}\right]^{\frac{1}{1-\theta}}. \tag{52}$$

4.4 Monetary authority

The central bank manages the short-term nominal interest rate, R_t, in response to deviations of output, y_t; CPI inflation, $\pi_t = P_t/P_{t-1}$; and the real exchange rate, $s_t = e_t P_t^* / P_t$. Thus, the monetary policy rule evolves according to:

$$\log(R_t/R) = \varrho_y \log(y_t/y) + \varrho_\pi \log(\pi_t/\pi) + \varrho_s \log(s_t/s) + \varepsilon_{Rt}, \tag{53}$$

where R, y, π, μ, and s are the steady-state values of R_t, y_t, π_t, and s_t, and where ε_{Rt} is a zero-mean, serially non-correlated monetary policy shock with standard deviation σ_R.

4.5 The government

The government budget constraint is given by:

$$P_t g_t + I_t + bd_{t-1} = \tau_l W_t h_t + \tau_t (R_{kt} - \delta) k_t + M_t - M_{t-1} + \frac{bd_t}{R_t}. \tag{54}$$

The left-hand side of (54) represents uses of the government revenue: goods purchases, transfers, and debt payments. The right-hand side includes tax revenues on labour and capital, an increase in the money base, and newly issued debt.

The government also faces a no-Ponzi-game constraint:

$$\lim_{t\to\infty} \left(\prod_{l=0}^{t} \frac{1}{R_l}\right) bd_t = 0. \tag{55}$$

which, jointly with (54), implies that the present value of government expenditures equals the present value of tax revenue plus the initial stock of public debt, bd_0^g.

Public debt in this model is Ricardian in that, given bd_0^g and policy choices on government purchases and tax rates, the competitive equilibrium can be represented with a government debt path dictated by (54), or with adjustments in lumpsum transfers to households, I_t, by the amount required to balance the budget constraint each period. Then, the budget rule can be rewritten as:

$$P_t g_t + I_t = \tau_l W_t h_t + \tau_t (R_{kt} - \delta) k_t + M_t - M_{t-1}. \tag{56}$$

This assumption implies a null domestic bond value, bd_t, at each period.

The following exogenous and independent process for government spending is defined:

$$\log(g_t) = (1 - \rho_g)\log(g) + \rho_g \log(g_{t-1}) + \varepsilon_{g,t}, \tag{57}$$

where $\varepsilon_{g,t}$ is zero mean normally distributed orthogonal innovations with standard deviation σ_g.

5 Estimation Methodology

A set of key parameters, Θ, is estimated by using the minimum-distance (M-D) method. Therefore, some impulse responses are chosen from section 3 and the structural parameters are selected that minimize the distance between these impulses and those generated by the theoretical model. The chosen responses should contain enough information to capture the whole set of parameters that are to be identified. This technique is used by Rotemberg and Woodford (1997), Christiano, Eichenbaum, and Evans (2001), and Boivin and Giannoni (2002), using monetary policy shock effects as a reference. In addition, Smets and Wouters (2002) apply the M-D method for a small open economy, in order to estimate the degree of price stickiness using responses to monetary and exchange rate shocks. More recently, Bouakez and Rebei (2003) adopt this method, focusing on impulse responses to a government spending shock, and find similar results with maximum likelihood using U.S. data. The advantage of this technique is that it focuses on only a subsample of structural shocks. In fact, unlike other common techniques (e.g., GMM, simulated method of moments, and maximum likelihood), it is not the intention of this technique to produce some unconditional moments observed in the data. Therefore, the analysis can be restricted to the reaction of a number of variables to shocks that can be interpreted as conditional moments.

Define Ψ as the vector of targeted conditional moments. $\widehat{\Theta}$ is the value minimizing

$$\left[g(\Theta;\Psi)\right]' V^{-1} \left[g(\Theta;\Psi)\right], \tag{58}$$

where g is a function depending on the structural parameters, given that the impulse responses produced by the model are sensitive to Θ. V is a diagonal matrix that contains the variances of the conditional moments. The minimization is achieved by setting to 0 the derivative of the expression (58) with respect to Θ. Then $\widehat{\Theta}$ is the solution of the system of non-linear equations:

$$\left\{ \frac{\partial g(\Theta;\Psi)}{\partial \Theta'}\bigg|_{\Theta=\widehat{\Theta}} \right\}' V^{-1} \left[g(\widehat{\Theta};\Psi)\right] = 0. \tag{59}$$

In the following, the estimation process is based on a vector, Ψ, consisting of the first five years of impulse-response functions of the government spending shock generated by the semi-structural VAR for consumption, investment, imports, exports, CPI inflation, and nominal interest rates.

5.1 Estimation results

Table 3 reports the estimated parameter values with their standard errors in parentheses.[8]

It is difficult to estimate all parameters simultaneously. The model is partitioned into groups of estimated parameters and calibrated parameters based on the estimates of similar models or microeconomics studies. To assign values for η_1, the equilibrium money-demand equation is used at the steady state. Once ω_2 is fixed, η_1 is set to 0.28 in order to satisfy the long-run relationship between consumption, money balances, and the interest rate. The parameter η_2 in the utility function is chosen to imply that, at the steady state, the household devotes 31 per cent of the time to hours worked. The intertemporal elasticities of substitution, ω_1 and ω_2, are set to 2, and ω_3 to 1. The elasticity of substitution between differentiated intermediate goods is restricted in both sectors, local and importing intermediary firms, θ and ϑ, equal to 8. This value implies a steady-state markup of price over marginal cost of less than 14 per cent. Basu's (1995) findings lead to a similar value. I set the elasticity of substitution between labour skills, σ, to 6, which corresponds to the estimates obtained by Ambler, Guay, and Phaneuf (2003). This parameter value is consistent with the micro-evidence produced by Griffin (1992) using disaggregated firm-level data. While these elasticities are useful for determining the long-term level of the monopolistic level of markup, they have a weak role in determining the model's dynamics. The constant rate of depreciation, δ, is equal to 0.025, corresponding to an annual rate of 10 per cent. The share of labour in the production function, α, is set to 0.35.

The last subset of parameters embodies the autoregression coefficient and the error standard-deviation of government spending, ρ_g and σ_g, the elasticity of substitution between private and public goods, ζ, the habit-formation parameter, γ, the degree of openness, α_d, the parameter of the risk premium, φ, the degree of price rigidity, $d_p = d_m$, the degree of wage rigidity, d_w, elasticity of substitution between imported and locally produced goods in the domestic aggregate demand, ν, the subjective discount factor, β, the parameter of capital adjustment costs, and the parameters that reflect the reaction functions of the monetary authority, ρ_π, ρ_y, and ρ_s.

Some parameters in the model are so intimately related that they cannot be distinguished from each other, as with the utility parameters a, ζ, and ω_1. The parameter ω_1 is less controversial; therefore, it is fixed. The elasticity of substitution between private and public consumption, ζ, is then estimated; it is a key parameter in the model, given the value of a, which represents the share of private goods in total consumption. Thus, two versions of the model are estimated: case 1, with $a = 0.8$, and case 2, with $a = 0.9$.

Table 3 shows the point estimates and their corresponding standard deviations. The

[8] To compute the standard errors for the estimated parameters, the following methodology is used. Define Θ_0 as the true values of the parameters, and D as a matrix with dimensions $(a \times r)$, where a is the number of conditional moments in Ψ, and r is the number of parameters in Θ. For any sequence $\{\Theta_T^*\}_{T=1}^{\infty}$ satisfying $\Theta_T^* \xrightarrow{p} \Theta_0$, D is described by the expression $plim\left\{\frac{\partial g(\Theta,\Psi_T)}{\partial \Theta}\Big|_{\Theta=\Theta_T^*}\right\} = plim\left\{\frac{\partial g(\Theta,\Psi_T)}{\partial \Theta}\Big|_{\Theta=\Theta_0}\right\} \equiv D$, with the columns of D being linearly independent. It can then be shown that $\sqrt{T}\left(\Theta - \Theta_0\right) \xrightarrow{L} N(0, W)$, where $W = (D'\bar{V}D)^{-1}$.

parameter estimates are precise and the model is clearly not rejected by the data. A considerable degree of complementarity is estimated between private and public consumption, $\zeta = 0.2921$ and 0.2648, respectively, for the first and second case.[9] The habit-formation estimate is lower than previously reported in the literature (e.g., Fuhrer 2001 and Bouakez, Cardia, and Ruge-Murcia 2002). The estimated value is 0.5084 (0.4850) in case 1 (case 2). The degree of openness is found to be equal to 0.7543 (0.7302), which seems plausible for the Canadian economy. The estimated value of φ is -0.0573 (-0.0580), which reflects, roughly, a level of foreign debt over GDP of 10 per cent. The probabilities of leaving prices and wages unchanged stand between 4 and 5 quarters. Estimates of d_p and d_w are consistent with the consensus in the literature based on Taylor's (1999) survey of the U.S. post-war economy. Both the elasticity of substitution between local and foreign goods in the domestic basket, ν, and the elasticity of foreigners' demand for domestic goods, ς, are constrained to be identical. The parameters ν and ς are found to be equal to 0.9405 (0.9312). Given these values, the sum of imports and exports elasticities exceeds one, so the static Marshall-Lerner condition is satisfied by the model. Dib (2003) estimates these two parameters in a small open economy using data from Canada and the United States and a maximum-likelihood procedure with a Kalman filter. He finds a value of 0.79 once ν and ς are constrained to be equal. Ambler, Dib, and Rebei (2003) estimate both parameters using an SMM procedure and find similar results. Their results also suggest that it is not possible to reject the hypothesis that ν and ς are identical. The discount factor is reasonably and precisely estimated to a value of 0.9937 (0.9983). ϖ gives the relative weight on the composite good used as an input in the production of domestic intermediate goods, which corresponds to 0.2145 (0.1973). This value is higher than the corresponding Ambler, Dib, and Rebei (2003) estimate (0.29), which I believe is attributable to the introduction of capital in the model as a production input. The parameters ρ_π, ρ_y, and ρ_s are intended to capture a fairly standard Taylor rule. Given that ρ_π is greater than unity, this ensures long-run inflation level determinacy. Since the responses of inflation and the interest rate are introduced as conditional moments in the M-D procedure, the monetary reaction function can be identified. The results are very reasonable and informative: the Bank of Canada during the sample period is aggressive enough to allow for determinacy ($\rho_\pi = 1.4452$). Furthermore, the monetary authority seems to care significantly about the output gap with a positive coefficient equal to 0.1918 (0.2398), but not about deviations of the real exchange rate from a targeted level, reflected by a very low and statistically non-significant coefficient ρ_s corresponding to -0.0215 (0.0582).[10]

[9] As Bouakez and Rebei (2003) show, the reference upper level for complementarity between private and public consumption is $\frac{1}{\sigma}$, which corresponds to 0.5 given the calibration. $\zeta < \frac{1}{\sigma}$ represents a necessary condition, but not sufficient to crowd-in total consumption in response to a positive government spending shock.

[10] Lubik and Schorfheide (2003) estimate Taylor rules within a general-equilibrium framework applied to small open economies using Bayesian methods. They focus on the conduct of monetary policy in Australia, Canada, New Zealand, and the United Kingdom. Their results show evidence that Canada does include a measure of exchange rates in its policy rule. This could be attributed to the model specification that lacks dynamics richness. Particularly, Lubik and Schorfheide's model generates complete pass-through between

6 Results

As Bouakez and Rebei (2003) show, a government spending shock can crowd-in private consumption under the necessary condition: $\frac{1}{\zeta} > \omega_1$ (Figure 3). Note that this condition is not sufficient: high complementarity is needed to drown the wealth effect caused by increasing government expenditures. For a closed economy, Bouakez and Rebei (2003) estimate this elasticity to be equal to 0.33.[11] Galí, Lopez-Salido, and Vallés (2002) combine rule-of-thumb consumers with price stickiness in order to replicate consumption crowding-in.[12]

Some previous studies consider the effect of opening the economy on the way local monetary shocks influence real aggregates. Clarida, Galí, and Gertler (2001) compare the effects of monetary policy in a closed *versus* open economy, using an optimal monetary policy rule, and find no evidence of substantial changes. The expenditure-switching mechanism, generally encountered in open economies, is not important enough when the model is hit with an unexpected change in nominal interest rates. As Figure 2 suggests, a similar result is obtained for the government spending shock, in that it allows for weak expenditure-switching.[13] Normally, an increase in public expenditure leads to a higher demand for imported goods, which puts pressure on the terms of trade, thereby generating real exchange rate depreciation. Consequently, it is possible to observe increased exports, hours worked, and output. Consumption increases less, given higher prices for imported goods. In a case of the latter sort, more private public goods complementarity is needed to retrieve a further consumption rise in response to an expansionary government spending shock. Moreover, this complementarity has to be higher if the weight on public consumption in total consumption, a, is lower. Given that estimation is based on the weighted deviation of the theoretical impulse responses from the empirical ones, if a lower percentage of public consumption enters utility, more complementarity (lower ζ) would be expected in order to stay close to the trajectory of empirical consumption.

Real imports and terms-of-trade reactions are intimately linked to the degree of substitution between domestic and foreign goods in the aggregate demand for final products captured by the parameter ν. Less substitution generates weaker expenditure-switching, in which case responses in an open economy will be close to the ones obtained in a closed economy.

Habit formation, as expected, introduces persistence in consumption and investment

the nominal exchange rate and local prices.

[11] Bouakez and Rebei use two methods to estimate the structural parameters within a general-equilibrium framework. The maximum likelihood and M-D between the VAR's and the model's impulse-response functions lead to very similar results using U.S. data.

[12] Intuitively, rule-of-thumb consumers decide to increase their consumption once positive innovation in public spending occurs in response to an increase in real wages. Combined with non-frequent price adjustments, this will lead to a higher rise in consumption, given the exaggerated jump of the real wage. With a high proportion of irrational households, the aggregate consumption can rise, especially if a low autoregression coefficient is assumed in the government spending process.

[13] In the estimation, however, it is possible to identify a degree of openness that is different than 1, which suggests the existence of a small amount of expenditure-switching.

responses. Surprisingly, when the parameter of habit formation is sufficiently high, this can offset the initial positive effect of an increase in public expenditures, leading to a decrease in real consumption. Estimation results suggest a reasonable level of habit formation of about 0.5084, which stands in the range of other estimates.[11]

To this point, the responses to a tax shock have not been discussed, but, generally, the model behaves properly given the sign of different responses. Notably, the model does very well for exchange rate responses to a shock on labour or capital taxes. This can be explained as follows: on the one hand, higher effective labour taxes today lead to intertemporal substitution of today's labour in favour of future labour. This would lower output in the short term, and then exports would decrease and the real exchange rate would appreciate. On the other hand, higher effective capital tax rates decrease capital, which would decrease labour productivity and drive output to decrease and the terms of trade to increase.

At this stage, the model does well for the major real variables in terms of responses of output, consumption, investment, exports, and imports to government spending shocks, but not for real exchange rate and inflation responses. Apparently, it is hard to reconcile the model with results of the VAR for real exchange rate responses. In fact, for different expansionary demand shocks, such as government spending *versus* tax rates, the real exchange rate reponds following opposite signs.

7 Monetary Policy and the Transmission of Fiscal Shocks

In the case where the interest rate is allowed to adjust to changes in the output gap, monetary policy will be able to decrease the effects of government spending on output. For a reasonable value of ϱ_y, there is a positive effect of fiscal expansion on output and a negative effect on inflation. Figure 4 shows that, when the monetary authority does not react to the output gap, output, inflation, and investment increase strongly, while consumption increases initially and remains positive for roughly 4 quarters. The intuition behind this finding is that, when the central bank reacts to an increase in the output, this lowers the demand effect of an increase in government spending, given that interest rates are pushed higher. Consequently, the aggregate demand increase is weakened, which decreases the need for firms to engage more labour input, even if the labour supply is higher due to the negative wealth effect that households still support. In addition, investment decreases in the first quarter given the increase in its cost. Note that the decrease in investment in the initial case is intimately related to the expenditures-switching effect that offsets wealth effects as a direct impact of an expansionary policy on public spending. The impact of the positive fiscal shock in the case where monetary policy adjusts will be spread through interest rates to inflation. Furthermore, ϱ_y can be large enough to induce a decrease in the inflation rate that forces the central bank to adjust its policy by lowering nominal interest rates while real interest rates increase. This case is illustrated in Figure 4, where the impulse responses are simulated for $\varrho_y = 0.5$.

[11] See, for instance, Christiano, Eichenbaum, and Evans (2001), Fuhrer (2001), and Bouakez, Cardia, and Ruge-Murcia (2002).

The results show that ϱ_s plays the same role as ϱ_y in the monetary interest rule. Contrary to the case where the monetary authority does not react to the real exchange rate gap, inflation decreases for the same reasons given in the previous paragraph, and the upward jump of output is attenuated. In addition, the decline in real investment is more pronounced in this case, given the nominal interest rate and inflation reactions. Compared with the case of the output gap, the inflation response is more sensitive to the monetary reaction to the exchange rate gap. To summarize, introducing the central bank's adjustment to the output gap and/or real exchange rate gap helps the model to replicate the short-term decreases in both investment and inflation that are observed empirically.

Counterfactual exercises, conducted by allowing the Taylor rule parameters, ϱ_s or ϱ_y, to be different from zero, exhibit a contractionary impact on aggregate demand. When ϱ_s or ϱ_y, or both, are high enough, an increase in government spending can lead to a decrease in the inflation rate that could be important enough to generate lower interest rates. Consequently, a shock to government spending can have negative effects on inflation. In addition, for some values of ϱ_s and ϱ_y, the output response can be negative. Generally, these parameters are estimated to be close to zero (e.g., Bergin 2003, Dib 2003, and Ambler, Dib, and Rebei 2003).

8 Conclusion

In this paper, I have studied the fiscal policy effects in a small open economy, in particular the Canadian economy. I have identified empirically different structural innovations that result from disaggregated fiscal decisions using a semi-structural VAR while focusing on the process by which the fiscal authority arrives at a policy decision. I have found some counterintuitive results concerning the responses of consumption, inflation, and the real exchange rate to unexpected increases in government expenditure.

I have developed a model that closely resembles the characteristics of the Canadian economy based on the new neoclassical synthesis framework. Once a positive public expenditures shock shows up, the model is able to generate crowding-in for consumption accompanied by investment crowding-out, and a fall in inflation. The model's main shortcoming, as the empirical analysis has shown, is its inability to generate the appreciation of the real exchange rate once the government increases expenditures for goods and services. This poses a challenge to the existing small open-economy framework. One alternative is to refine the way in which a fiscal authority finances public expenditures, taking into account changes in taxes and the public debt within a non-Ricardian environment.

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Table 1: GMM Parameter Estimates

(standard deviations in parentheses)

Parameter	GMM estimation (*std*)	*tstat* (*p*-value)
σ_π	0.0040 (0.0003)	12.7144 (0.0000)
σ_l	0.0048 (0.0005)	8.9927 (0.0000)
σ_k	0.0078 (0.0005)	16.3680 (0.0000)
σ_g	0.0102 (0.0008)	13.4254 (0.0000)
σ_r	0.0067 (0.0007)	9.2662 (0.0000)
σ_y	0.0069 (0.0004)	16.6077 (0.0000)
γ_1^l	0.3789 (0.0495)	7.6485 (0.0000)
γ_2^l	0.0858 (0.0362)	2.3726 (0.0247)
γ_1^k	0.3789 (0.0495)	7.6485 (0.0000)
γ_2^k	0.0654 (0.0471)	1.3898 (0.1516)
γ_1^r	0.2592 (0.1158)	2.2376 (0.0334)
γ_2^r	−0.0126 (0.0946)	−0.1336 (0.3947)
γ_3^r	−0.1155 (0.0522)	−2.2117 (0.0354)
γ_4^r	−0.2024 (0.0870)	−2.3269 (0.0274)

J-stat=5.6588, p-value=0.5801

Table 2: Effects of Fiscal Variables on GDP Components and Prices

Variables	Shocks: Labour tax						Capital tax						Government spending					
	1Q	8Q	12Q	20Q	Max.	Min.	1Q	8Q	12Q	20Q	Max.	Min.	1Q	8Q	12Q	20Q	Max.	Min.
1-GDP Components																		
Consumption																		
Total	0.00	-0.79*	-0.29	-0.11	0.00(1)	-0.79*(1)	0.00	-0.29*	-0.21	0.09	0.00(1)	-0.31*(6)	0.03	0.04	0.15	0.13	0.15(12)	-0.01(2)
Non-Durables	0.00	-0.20*	0.40	0.64*	0.64*(20)	0.20*(1)	0.00	-0.02	0.23	0.12	0.12(20)	-0.02(1)	0.01	0.20*	0.11	0.07	0.20*(1)	0.01(1)
Semi-Durables	0.00	-1.50*	-0.92*	-0.34*	0.00(1)	-1.50*(1)	0.00	-0.17	0.32	0.76*	0.76*(20)	-0.17(1)	0.19*	0.29*	0.12	-0.08	0.29*(1)	-0.08(20)
Durables	0.00	-1.91*	-0.54	0.01	0.01(20)	-1.91*(1)	0.00	-0.80*	-0.22	0.52	0.52(20)	-1.00(6)	-0.05	-0.03	0.10	0.01	0.39*(3)	-0.05(1)
Services	0.00	-0.37*	0.27	0.18	0.27(12)	-0.37*(1)	0.00	-0.21*	-0.21*	-0.06	0.00(1)	-0.25*(9)	0.01	-0.05	0.11*	0.16*	0.17*(18)	-0.05(1)
Investment																		
Total	0.00	-1.17*	-1.10*	-0.82	0.00(1)	-1.59*(6)	0.00	-0.22	-0.12	0.16	0.16(20)	-0.44(10)	-0.15	-0.23	-0.01	0.31	0.32(19)	-0.50*(7)
Residential	0.00	-3.31*	0.02	-0.38	1.02(9)	-3.31*(1)	0.00	-0.66*	-0.50	-0.17	0.00(1)	-0.66(10)	-0.28*	-0.11	0.63*	0.39	0.66*(10)	-0.63*(2)
Non-Residential	0.00	-0.80*	-1.87*	-1.30	0.00(1)	-2.11*(15)	0.00	-0.11	-0.68*	0.07	0.16(6)	-0.68*(12)	0.07	-0.16	-0.37	-0.07	0.05(3)	-0.091(7)
Inventories	0.00	-3.57*	1.87	3.61*	3.61*(20)	-7.51*(5)	0.00	1.15	-0.07	2.49*	2.18*(20)	-2.22*(7)	-0.52	-1.98*	0.99	0.05	1.29*(10)	-1.98*(4)
Exports	0.00	-1.12*	0.16	1.16*	1.16*(20)	-1.12*(1)	0.00	0.29	0.65*	0.69*	0.82(16)	-0.10(5)	0.15	0.21	0.28	0.10	0.11*(9)	-0.04(3)
Imports	0.00	-0.54	2.33*	1.90*	2.37*(11)	-0.54(1)	0.00	0.53	0.98*	0.82*	1.05*(15)	0.00(1)	0.30	0.14	0.12	0.15	0.51*(9)	0.14(1)
2-Prices																		
Exchange Rate	-0.00	-0.13*	-1.11*	-0.80*	-0.00(1)	-1.87*(8)	-0.00	-0.22	-0.32	-0.31	-0.00(1)	-0.59*(8)	0.10	-0.13	-1.21*	-0.87*	0.10(1)	-1.27*(13)
Real Wages	0.00	0.21	-0.46*	0.12	0.21(1)	-0.61*(8)	0.00	0.26*	-0.05	-0.03	0.31*(5)	-0.18(15)	-0.01	-0.04	-0.07	-0.53	0.10(8)	-0.53*(20)

*: Statistically significant.

Table 3: Minimum-Distance Estimation Results

(standard deviations in parentheses)

Parameter	Case 1: $a = 0.80$	Case 2: $a = 0.90$
ρ_{ij}	0.9527 (0.0353)	0.9492 (0.0361)
σ_{ij}	0.0090 (0.0034)	0.0090 (0.0034)
ζ	0.2921 (0.0996)	0.2648 (0.0761)
γ	0.5084 (0.0503)	0.4850 (0.0549)
α_{ij}	0.7543 (0.3037)	0.7302 (0.0410)
τ	−0.0573 (0.0568)	−0.0580 (0.1137)
d_{ii}	0.7787 (0.1267)	0.7848 (0.0501)
$d_{ji} = d_{ii}$	0.7102 (0.1707)	0.6976 (0.0601)
$\kappa = \nu$	0.9405 (0.0723)	0.9312 (0.0368)
β	0.9937 (0.1263)	0.9983 (0.0829)
ϕ	0.2145 (0.0698)	0.1973 (0.0390)
σ_k	48.4921 (8.1698)	35.9556 (3.5445)
ρ_{ii}	1.4452 (0.1101)	1.7674 (0.0441)
ρ_{ij}	0.1918 (0.0629)	0.2398 (0.0346)
ρ_{ii}	−0.0215 (0.1240)	0.0582 (0.0203)
Function Value	84.2786	87.2389

Figure 1: Empirical Impulse-Response Functions

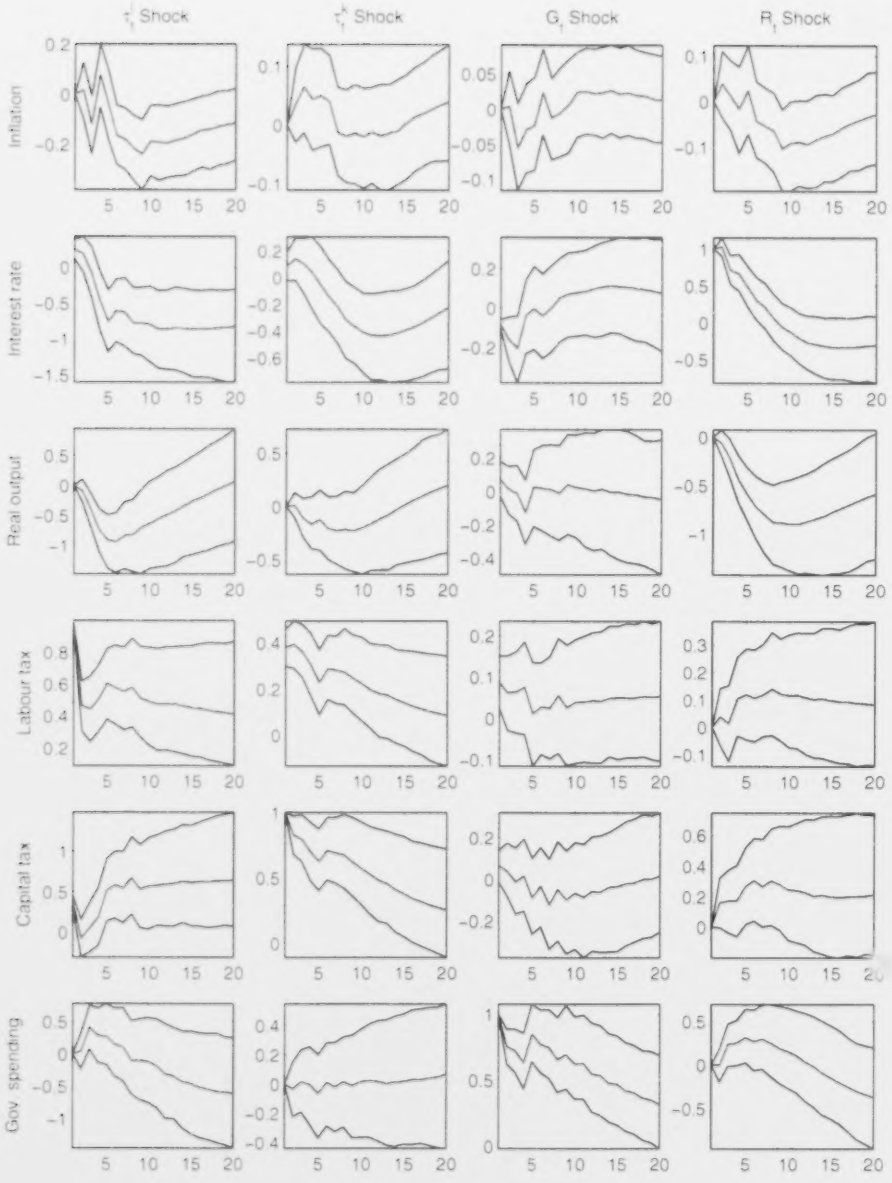


Figure 2: Open versus Closed Economy (++: $\alpha_d = 0.7543$, oo: $\alpha_d = 1.0$)

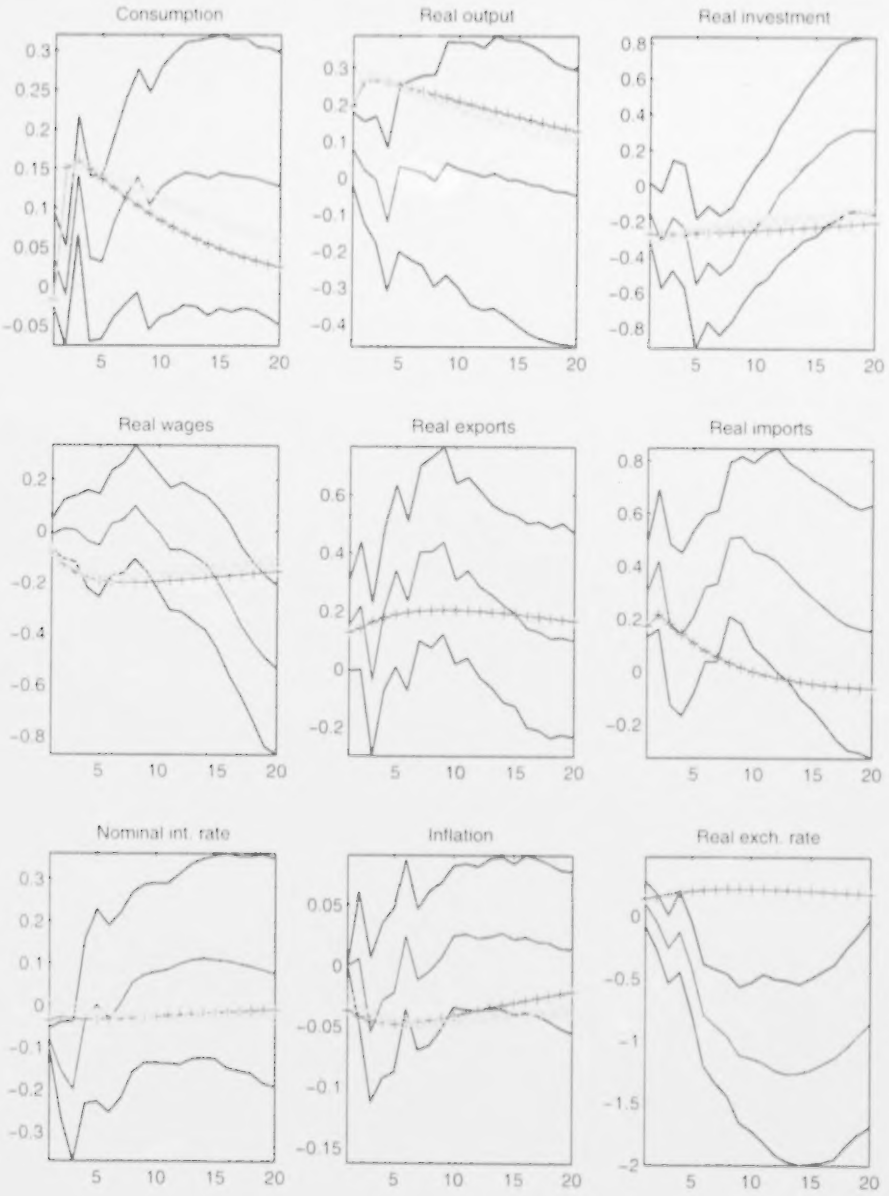


Figure 3: Role of Private and Public Consumption Substitution (++: $\zeta = 0.2921$, oo: $\zeta = 1.0$)

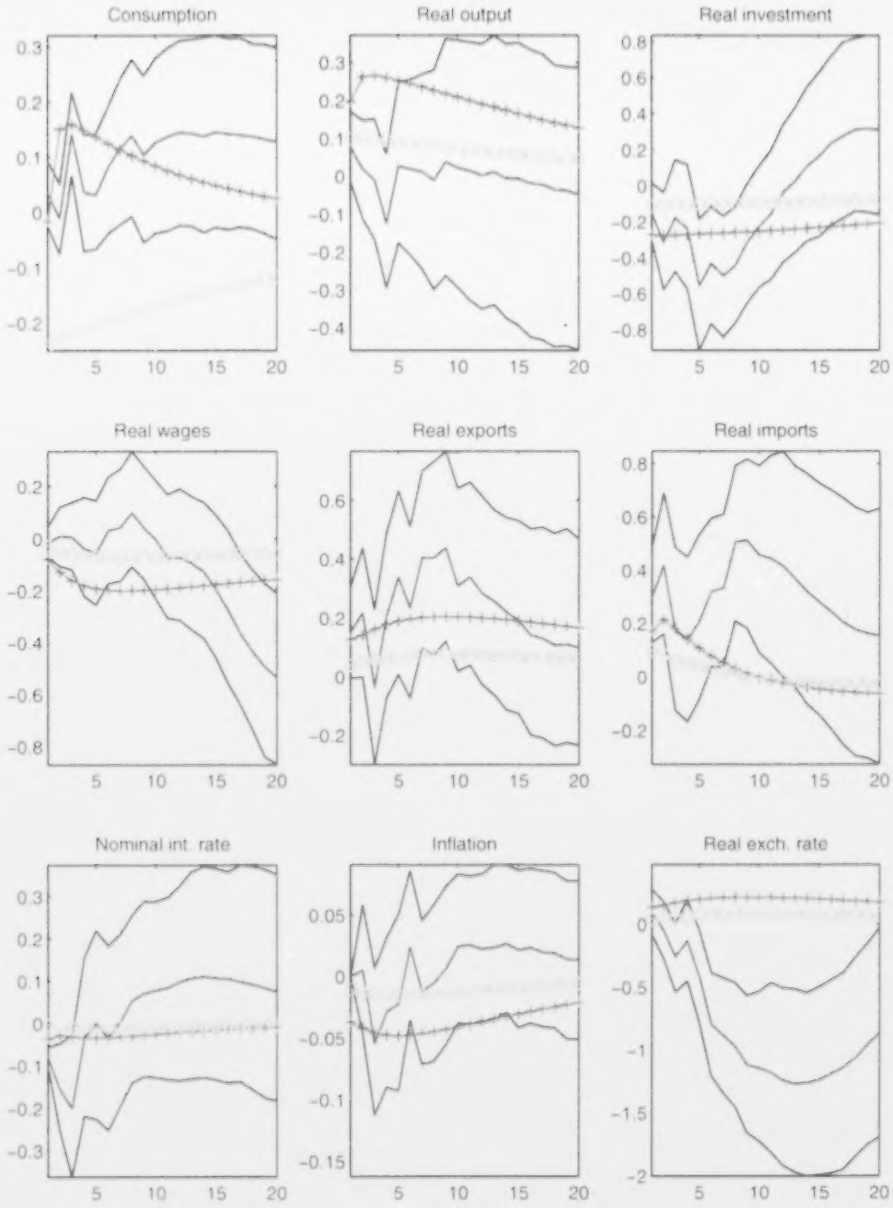
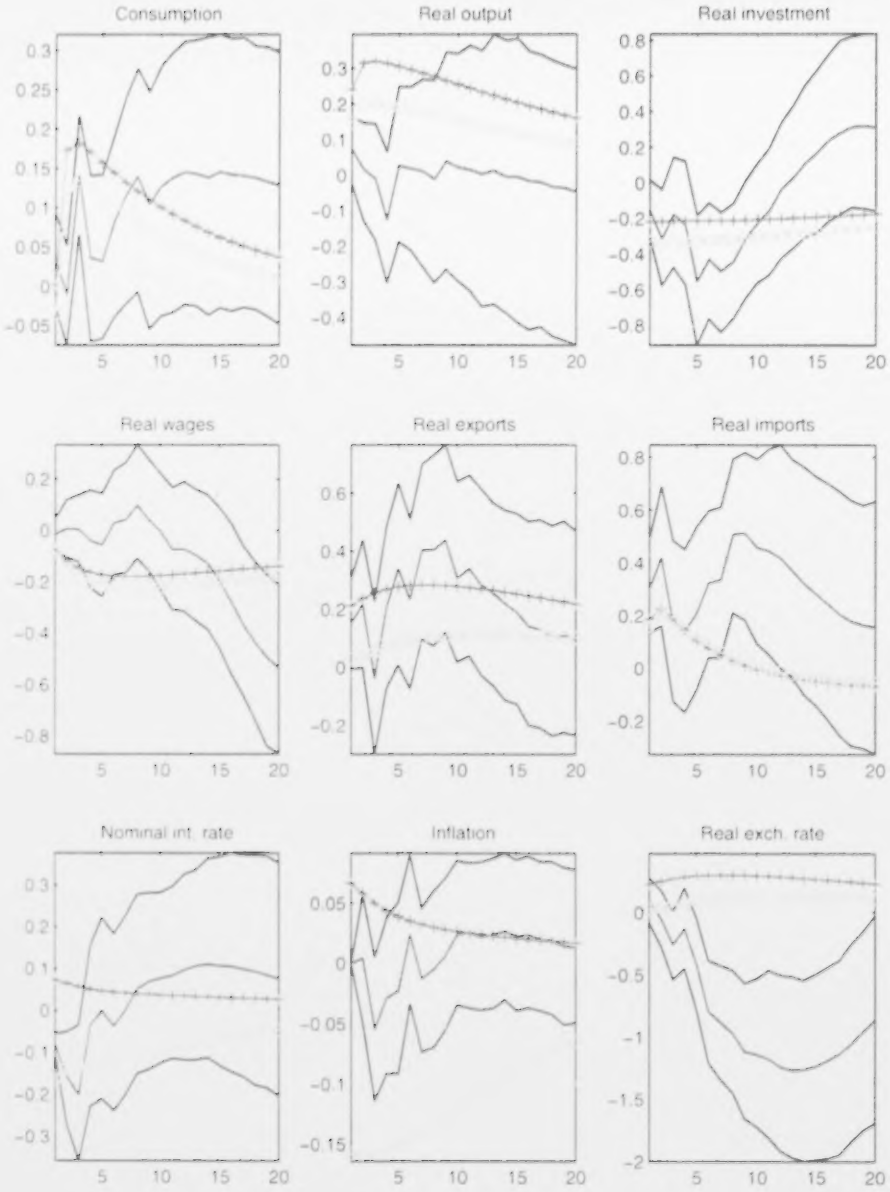


Figure 4: Effect of Taylor Rule Specification (++: $\varrho_y = 0$, oo: $\varrho_y = 0.5$.)



Appendix: Construction of Average Tax Rates

To replicate the methodology employed by Jones (2002), and Mendoza, Razin, and Tesar (1994), the following Canadian series were obtained from the CANSIM database.

- v498317: Federal Income Taxes (FIT)
- v499818: State Income Taxes (SIT):
- v498076: Wage (W):
- v498170: Unincorporated Business Net Income (UBI) = Proprietor's Income + Rental Income:
- v498077: Corporation Profits (CP):
- v498079: Net Interest (NI):
- v499737: Contributions to Social Insurance Plan (CSI):
- v499680: Corporate Income Tax (CT):
- v499942: Property Tax (PT).

The main assumption when using effective average taxes is that taxation of all the resources of individuals is uniform. Therefore, tax revenue resources typically do not provide a breakdown of individual income tax revenue in terms of labour and capital income.

First, the household's average tax rate on total income, τ_h, is computed:

$$\tau_h = \frac{FIT + SIT}{W + CI} \times 100. \tag{A.1}$$

where $CI = UBI + CP + NI$. Thus, the total income tax rate is the ratio of individual income tax revenue to pre-tax individual income.

The effective average tax rate on labour income is computed as:

$$\tau_l = \frac{\tau_h(W + UIB) + CSI}{W + CSI} \times 100. \tag{A.2}$$

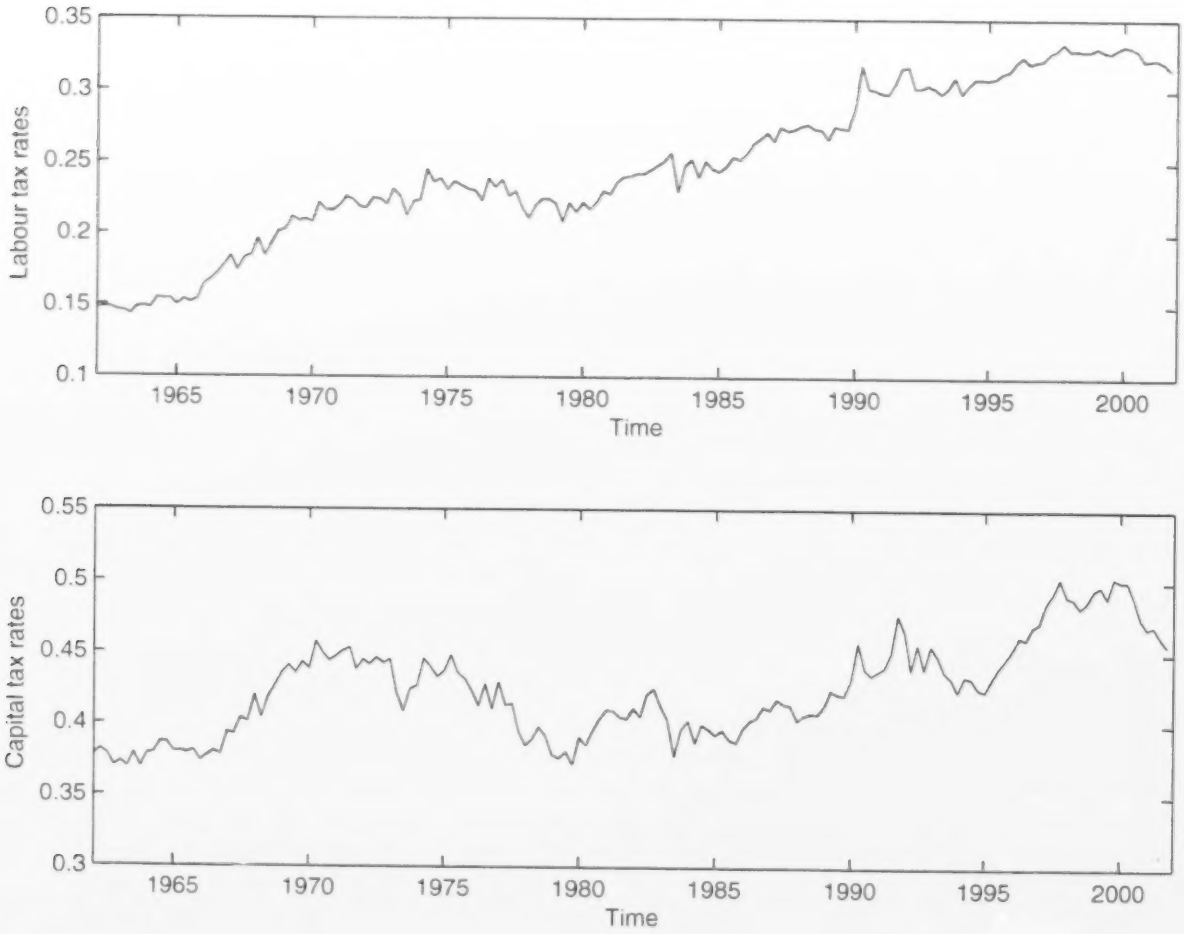
As in Mendoza, Razin, and Tesar (1994), the employers' contribution to social security is considered part of the revenue, and the tax base is increased according to the amount of these contributions, since households are not taxed on this portion of compensation.

The revenue from the capital tax on the individual is considered to correspond to $\tau_h CI$. The effective capital income tax rate is therefore:

$$\tau_k = \frac{\tau_h CI + CT + PT}{CI + PT} \times 100. \tag{A.3}$$

The constructed series for the effective labour and capital tax rates are reported in Figure A1.

Figure A1: Labour and Capital Tax Rates



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